Aluminum Nanowire Fabrication for use in Polarization Filters

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Abstract:

Polarization is a property of light that humans are incapable of seeing, but which contains a plethora of information. Material properties, shape, and surface properties can be determined from polarization, even if the image is hidden in a shadow. To take polarization images with a camera, a polarization filter on the nanoscale must be used. One type of filter is composed of aluminum nanowires. Aluminum and silicon dioxide are thermally evaporated onto a glass slide and then coated with poly(methyl methacrylate) (PMMA). Photolithography and reactive ion etching are used to create the nano features. Then a scanning electron microscope is used to check the features of the wires.

Introduction:

Intensity, wavelength, and polarization are the three main properties of light, however, humans are only able to see the first two. The polarization of light contains a plethora of useful information. Shape, surface characteristics, and material characteristics can all be determined from polarization information. Polarization is the angle at which the wave is oscillating as it propagates forward. In Figure 1, there are several orientations to the light approaching the filter even though it is all still moving in the same direction with the same wavelength. Each one of those different orientations represents a degree of polarization from 0 to 180 degrees.

Figure 1 illustrates how a polarization filter works. If the wires are aligned perpendicular to the plane of oscillation, the light is completely quenched. If they are parallel, then the light completely passes through. If nanowires are placed over the pixels of a camera, then different pixels in the camera will see different pieces of the polarization information.

There are many uses a polarization camera can have. For example, cancer cells have a different cell membrane composition than healthy cells. To the human eye, they both appear the same, but by viewing the polarization image, the cancer cells stand in sharp contrast to the healthy cells, making identifying cancerous tissue during surgery an easier process. Figure 2 shows two different images of the same horse. The first image shows the intensity information, while the second shows the polarization information. In the polarization image, the finer features of the horse are much more apparent compared to the intensity photograph. This is because the polarization information only relies on the angle and degree of polarization while the intensity depends on the amount of light present.

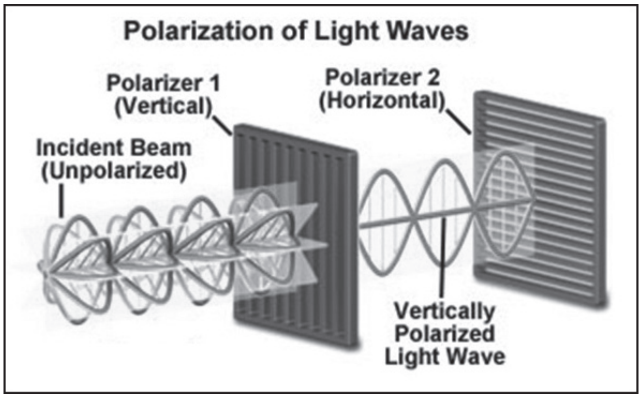


Figure 1: Polarized light interacting with a polarization filter.

Figure 2: Intensity image of a horse (left) and a polarization image of a horse (right).

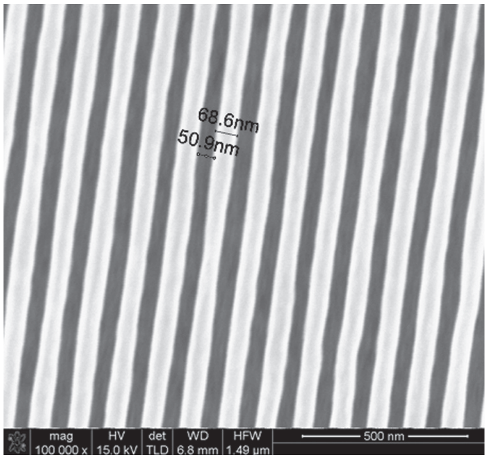
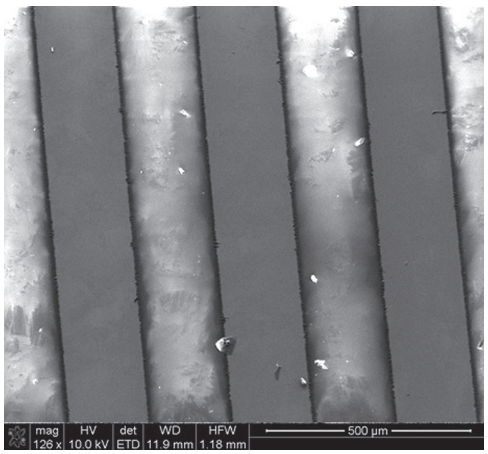


Figure 3, above: Nanowire pattern imprinted in PMMA.

Figure 4, below: Aluminum micro-wires after reactive ion etching.



Methods:

The production of the aluminum (Al) nanowires involved several steps. First, glass slides were coated in 140 nm of Al and 20 nm of silicon dioxide (SiO_2). The slides were then coated with poly(methyl methacrylate) (PMMA) to act as a soft mask. Electron beam lithography was used to imprint the nanowire patterns into the PMMA (Figure 3). The PMMA was developed by exposing the SiO_2 below.

An Oxford Plasmalab 100 reactive ion etch system was used to perform the etching. Hydrogen bromide was used to etch through the Al oxide layer and chlorine was used to etch the Al. This step was followed by an oxygen ashing step to burn off any remaining photoresist and remove the SiO_2.

The process was first optimized on a micro-sized wire (Figure 4) for speed and then moved to a nanoscale wire pattern.

Results and Discussion:

There were several difficulties in optimizing the fabrication of the Al nanowires. First, the photoresist had to be perfectly smooth for features to be entirely transferred to the SiO_2. This was most prominently an issue with regard to the edge bead. The increasing thickness of the photoresist, as it approached the edge, caused the lines to grow shallow closer to the edge. This created difficulties in viewing sidewall profiles. The addition of an edge bead remover helped to eliminate this problem, but also made uniformity hard to control.

The second difficulty arose when switching to the nanoscale. The etch recipe that had worked for the micro-wires removed everything when trying to etch the nanowires. Several new recipes using several gases were used, but none were selective enough to prevent over etching of the SiO_2 mask. In future attempts, trifluoromethane (CHF_3) will be utilized due to its higher selectivity to SiO_2 and its sidewall polymer formation, which will help to produce straighter sidewalls.

Once the optimization is completed nanowires of varying sizes should be able to be produced consistently for use in polarization cameras.

Acknowledgements:

I would like to thank Professor Viktor Gruev, Raphael Njuguna, and Shengkui Gao in the Electrical Engineering department, Nathan Reed and Kate Nelson with the clean room facilities, Dolores Stewart, and Melanie-Claire Mallison with the NNIN REU Program, and the Nano Research Facilities, NSF, and NNIN for funding.

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